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Arm Based Liquid Level Detection and Fluid Control System

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Abstract - Efficient liquid level detection and fluid control are crucial in various industrial and domestic applications, such as chemical processing, water management, and biomedical systems. This project presents an ARM-based liquid level detection and fluid control system using an STM32F1 03C8T6 microcontroller, designed for precise and automated fluid regulation.The system consists of two beakers, one for liquid level detection and the other for fluid flow regulation. Ultrasonic sensor continuously monitor the liquid level in the detection beaker. If the liquid level falls below a predefined threshold, the STM32F103C8T6 microcontroller activates a control mechanism to regulate the fluid flow from the second beaker to restore the desired level. The control algorithm ensures real-time adjustments, minimizing overshoot and preventing spillage.This ARM-based liquid level control system finds applications in industries requiring precise fluid handling, such as pharmaceuticals, food processing, and wastewater treatment. Future enhancements may include wireless monitoring, adaptive thresholding, and machine learning-based predictive control for further optimization

***Key Words*:** STM32F103C8T6, Liquid Level Detection, Fluid Control System, Water Level Measurement **,**Calibration Algorithm, Data Processing, Real-time Monitoring, Variable Power Supply, STM32CubeIDE / Keil / Arduino IDE, C/C++ for Embedded Systems, PWM Control.

1. INTRODUCTION

This project focuses on developing an ARM-based liquid level detection and fluid control system using the STM32F103C8T6 microcontroller. The system is designed to monitor and control liquid levels in a container using an ultrasonic sensor and a DC pump motor. The core objective is to ensure efficient fluid management by automatically controlling the liquid flow based on pre-defined threshold levels. The system integrates a 16x2 LCD for real-time level display, an relay for pump control, and a power supply unit to ensure reliable operation. By utilizing an ARM Cortex-M3-based STM32 microcontroller, the system ensures high-speed processing, low power consumption, and accurate liquid level measurement.

The ultrasonic sensor serves as the primary sensing component, transmitting ultrasonic waves to measure the liquid level in a beaker. The STM32 microcontroller processes the sensor data and determines whether the liquid level is below or above the threshold. If the level is too low, the microcontroller activates the DC pump via relay to refill the container. Conversely, if the level is too high, the pump is turned off to prevent overflow. This automation reduces the need for manual intervention and minimizes water wastage.

2. SYSTEM CONTENT

2.1 STM32F103C8T6 Microcontroller

The STM32F103C8T6 is a widely used microcontroller from STMicroelectronics, belonging to the STM32F1 series. It is built around the ARM Cortex-M3 core, offering a balance between performance and efficiency. With a clock speed of 72 MHz, it provides sufficient processing power for embedded applications while maintaining low power consumption. This microcontroller features 64 KB of Flash memory and 20 KB of SRAM, making it suitable for projects that require moderate memory and computational resources.

Designed for versatility, the STM32F103C8T6 supports multiple communication protocols, including USART, SPI, I2C, and CAN. These interfaces allow seamless connectivity with external components such as sensors, displays, and communication modules. The microcontroller also includes a 12-bit ADC with 10 channels, enabling precise analog-to-digital conversion, which is crucial for applications like signal processing and sensor interfacing. Additionally, it offers seven timers, including PWM support, which is beneficial for motor control and waveform generation.

Programming the STM32F103C8T6 is supported by several development environments, such as STM32CubeIDE, Keil uVision, and the Arduino IDE with STM32 core support. These tools provide a comprehensive platform for coding, debugging, and flashing firmware onto the microcontroller. Additionally, the ST-Link programmer is commonly used for debugging and uploading programs, ensuring smooth development and testing processes

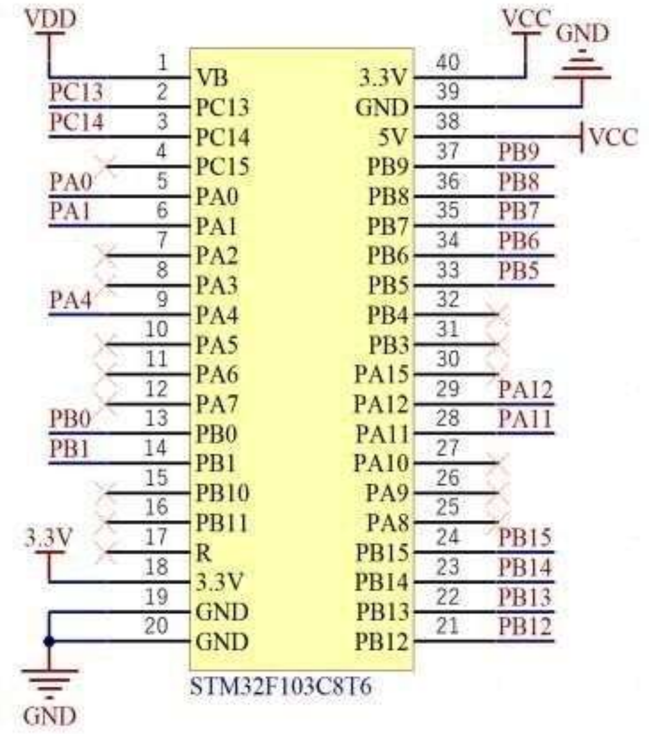

Fig 1

2.2 LCD DISPLAY (16X2)

The 16x2 LCD module is a widely used display unit in embedded system projects, capable of displaying 16 characters per line across two rows. It is based on the HD44780 controller, which makes it compatible with a variety of microcontrollers, including the STM32 series. Each character is formed using a 5x8 pixel matrix, allowing it to present letters, numbers, and custom characters. The module operates typically at 5V and includes a backlight for visibility, as well as a contrast control pin connected to a potentiometer for adjusting text clarity. It supports both 8-bit and 4-bit parallel communication modes; however, the 4-bit mode is commonly preferred to save GPIO pins. The LCD is controlled using key pins such as RS (Register Select), RW (Read/Write), and E (Enable), along with data pins D0 to D7. When using 4-bit mode, only the higher data lines (D4 to D7) are utilized. Commands and data are sent to the display by toggling these control and data lines in a specific sequence, with adequate timing delays. Common instructions include clearing the screen, positioning the cursor, and turning the display on or off. In STM32-based applications, the LCD can be interfaced using HAL libraries or direct GPIO programming. With simple wiring and easy code implementation, the 16x2 LCD remains a reliable choice for providing user feedback in microcontroller-based projects.

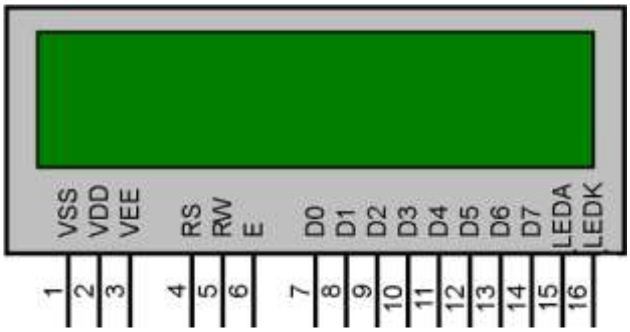

Fig 2 LCD DISPLAY (16X2)

2.3 ULTRASONIC SENSOR

The HC-SR04 ultrasonic sensor is widely used for distance measurement in embedded systems. It operates by sending out an ultrasonic pulse through its TRIG pin and measuring the time it takes for the echo to return to the ECHO pin after reflecting off a surface. When interfacing this sensor with an STM32 microcontroller, the TRIG pin is connected to a GPIO output, while the ECHO pin is connected to a GPIO input configured for precise timing. The STM32 sends a short 10 microsecond pulse to the TRIG pin to initiate the measurement. After the echo is received, the microcontroller uses internal timers to calculate how long the ECHO pin stays high. This time duration is then used to compute the distance using the formula: Distance = (Time × 0.0343) / 2, where 0.0343 cm/µs is the speed of sound. The use of timer interrupts or input capture mode on the STM32 ensures accurate measurements. This setup is especially useful in projects like liquid level detection, where real-time and reliable distance sensing is required.

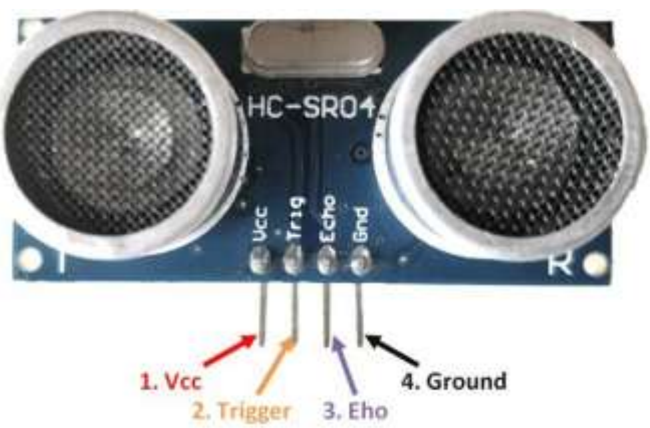

Fig 3 Ultrasonic sensor

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2.4 RELAY

In this ARM -based fluid control system, the relay serves as a key component for switching the small DC water pump on and off. The STM32F103C8T6 microcontroller cannot directly power the pump due to its limited current output. Instead, it sends a low-voltage signal from one of its GPIO pins to the relay module. When this signal is high, the relay coil is energized, causing the internal switch to close and connect the pump to the external power supply. This turns the pump ON. When the STM32 sets the signal low, the coil deactivates, the switch opens, and the pump is disconnected from power, turning it OFF. This setup allows the microcontroller to safely and efficiently control the pump based on real-time liquid level data from the ultrasonic sensor.

FIG 4 Relay

2.5 SMALL DC PUMP

To control a small DC pump using an STM32 microcontroller, a relay is used as an intermediary switch to handle the higher power required by the pump. The STM32 sends a low-voltage signal to the relay, which then triggers the relay's switch to connect or disconnect the pump's power supply. When the STM32 outputs a HIGH signal, the relay activates, completing the circuit and turning the pump ON. Conversely, when the STM32 sends a LOW signal, the relay deactivates, cutting off the power to the pump and turning it OFF. It's important to place a diode across the relay coil to prevent damage to the STM32 from voltage spikes generated when the relay coil is tued off.

Fig 5 SMALL DC PUMP

2.6 I2C

I2C (Inter-Integrated Circuit) is a two-wire communication protocol used for connecting microcontrollers to peripheral devices. It operates with a master-slave architecture, where the master (usually a microcontroller) controls the communication, and multiple slave devices, each with a unique address, can be connected to the same bus. I2C uses two lines: the Serial Clock Line (SCL) for clock signals and the Serial Data Line (SDA) for data transfer. The protocol allows for efficient communication at speeds up to 400 kbps (Fast Mode) or 1 Mbps (High-Speed Mode). Its simplicity, low wiring requirements, and ability to support multiple devices make it ideal for embedded systems and a popular choice in many applications.

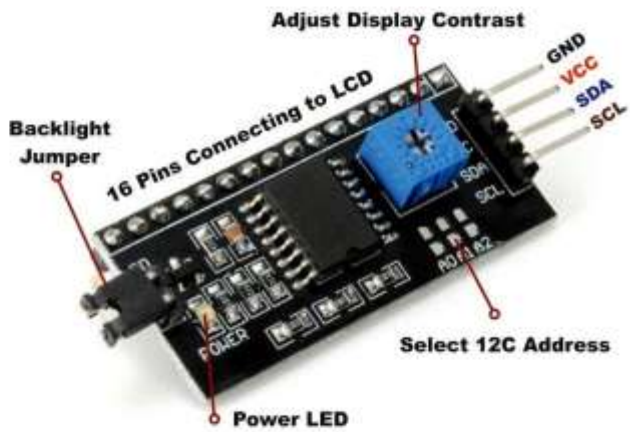

Fig 6 I2C

3. METHODOLOGY

The development of the ARM-based liquid level monitoring and control system is centered around the STM32F103C8T6 microcontroller, which orchestrates the interaction between various hardware components and implements the control logic. The primary sensor used for measuring the liquid level is an ultrasonic distance sensor, typically the HC-SR04. This sensor operates by transmitting high-frequency sound waves toward the surface of the liquid. These waves are reflected back from the surface, and the sensor measures the time taken for the echo to return. By applying the formula for distance calculation (Distance = Speed of Sound × Time / 2), the microcontroller converts the time-of-flight data into a measurable liquid level.Once the level is calculated, the microcontroller compares it with user-defined threshold values—specifically, a lower limit that signals an empty or low container, and an upper limit that indicates a full or nearly full container. If the measured level falls below the lower limit, the microcontroller sends a signal to a relay module. This relay acts as a switch to activate a small DC water pump, which begins refilling the container with liquid. As the liquid level rises and exceeds the upper threshold, the microcontroller again sends a signal to deactivate the relay, stopping the pump to prevent any spillage or overflow.The real-time status of the system, including the current liquid level and the pump's operational state, is displayed on an LCD screen. The LCD can communicate with the microcontroller either through I2C protocol or parallel communication, depending on the type of module used. This visual output allows users to monitor the system's performance without requiring any external tools.The software is developed using the STM32CubeIDE environment in Embedded C language. The programming approach follows an event-driven architecture, where sensor inputs are continuously monitored and processed in the main execution loop. Key functional steps include triggering the ultrasonic sensor, capturing echo duration, calculating the distance, comparing values against thresholds, activating or deactivating the pump via the relay, and updating the LCD output.To improve measurement accuracy and system stability, various optimization techniques are integrated into both hardware and software. For instance, the ultrasonic readings are filtered using a median filtering algorithm to eliminate random spikes or noise caused by environmental interference. A watchdog timer is also enabled within the STM32, which resets the system if it becomes unresponsive due to a software fault. Additionally, low-power operating modes are employed to reduce power consumption, making the system suitable for battery-operated environments. Electrical protections such as reverse polarity protection, overcurrent limiters, and flyback diodes across inductive loads are included in the circuit design to enhance safety and extend the system's operational life.Overall, the methodology ensures that the system operates in a fully autonomous manner—continuously monitoring the fluid level, making intelligent decisions based on predefined conditions, and taking actions to control the pump as required. This design achieves both precision and reliability, making it suitable for practical applications in areas such as household water tanks, industrial fluid reservoirs, and agricultural irrigation systems

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3.1 BLOCK DIAGRAM

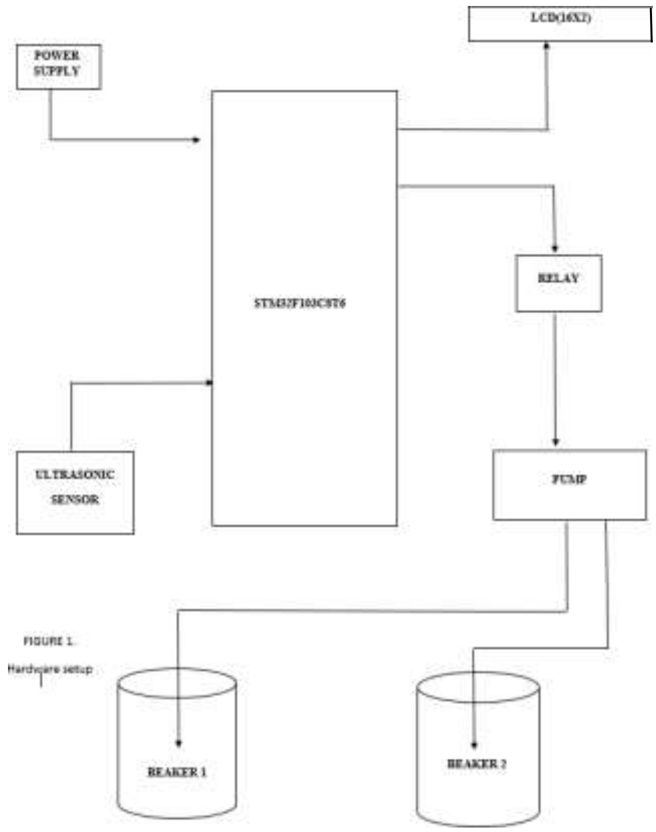

Fig 7 Block Diagram

4. RESULT AND DISCUSSION

The ARM-based liquid level detection and fluid control system using the STM32F103C8T6 microcontroller was successfully implemented to monitor and maintain the fluid level in a beaker with a height of 9 cm. An ultrasonic sensor was used to measure the distance between the sensor and the surface of the liquid, and this data was processed by the STM32 to calculate the actual liquid level. The system was calibrated so that a sensor reading of 9 cm corresponds to an empty beaker (0 cm liquid level), and a reading of 0 cm corresponds to a full beaker (9 cm liquid level). The liquid level was displayed in real-time on a 16x2 LCD screen, providing a clear visual indication of the current status. A DC water pump, controlled via relay, was automatically activated or deactivated based on the measured liquid level. For example, when the liquid level dropped below a certain threshold, the pump turned on to refill the beaker, and once the desired level was reached, it automatically turned off. This closed-loop system ensured efficient and accurate fluid control. The project met all its intended objectives, demonstrating precise sensor data processing, reliable pump control, and effective real-time display, making it suitable for small-scale liquid level automation and offering a strong foundation for future scalability and industrial applications.

In the ARM-based liquid level detection and fluid control system, a set point value of 3 cm is defined from the ultrasonic sensor. When the liquid level reaches 3 cm from the ultrasonic sensor, the STM32 microcontroller sends a LOW-level signal to the relay, which turns OFF the water pump. If the liquid level falls below 3 cm (i.e., the distance from the sensor increases beyond 3 cm), the STM32 sends a HIGH-level signal to the relay, which turns ON the pump to refill the beaker. The overall height of the beaker is 9 cm, and the system maintains the liquid level based on this calibrated set point to ensure accurate fluid control.

Fig 8

Case 1: Liquid Level < 3 cm

When the liquid level was less than 3 cm from the ultrasonic sensor, the system determined that the container had enough liquid. In this condition, the STM32F103C8T6 microcontroller sent a LOW signal to the relay, causing the motor to remain OFF. This action prevented the pump from operating unnecessarily, helping to conserve both energy and liquid. Additionally, the LCD display showed the message "Level OK – Motor OFF" to indicate the current status to the user.

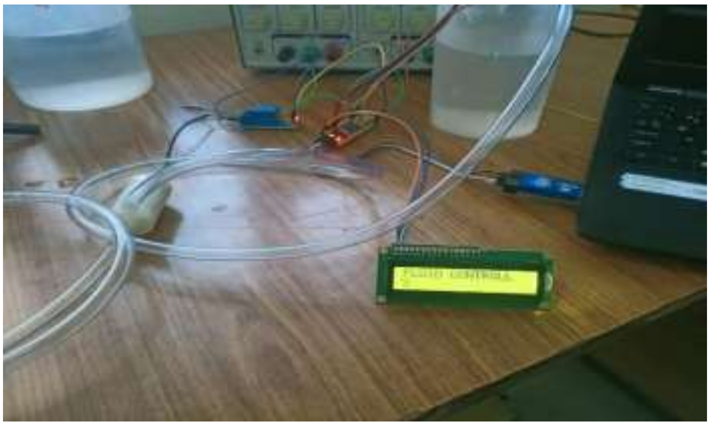

Fig 9

Case 2: Liquid Level ≥ 3 cm

When the liquid level reached 3 cm or more, the system detected that the liquid level was low and required refilling. The STM32F103C8T6 responded by sending a HIGH signal to the relay, which activated the motor. This allowed water to be pumped into the container to restore the desired liquid level. During this condition, the LCD displayed the message "Level Low – Motor ON" to clearly inform the user about the ongoing pumping process.

DISCUSSION

This project focuses on the development of an automated liquid level monitoring and control system, tailored for applications in sectors such as industrial fluid handling, water treatment, and laboratory automation. At the core of this system is the STM32F103C8T6 microcontroller, which is part of the ARM Cortex-M3 series, known for its efficiency and reliability in embedded systems.The system relies on an ultrasonic sensor to detect the height of the liquid in a beaker. It does so by sending out ultrasonic pulses and measuring the time taken for the echo to reflect back from the surface of the liquid. This time delay is then converted into distance by the microcontroller, which determines the current fluid level.Based on the calculated level, the STM32 executes control logic. If the detected level falls below a certain threshold, it activates a DC water pump through a relay driver circuit. The pump transfers fluid from one beaker to another to maintain the desired level. Once the target level is reached, the system stops the pump, ensuring there's no overflow or wastage.A variable power supply ensures consistent voltage and current delivery to all components, reducing the chances of malfunction due to power fluctuations. An LCD display is also integrated to provide real-time updates on the fluid level, system status, and pump activity, offering better transparency and monitoring.One of the challenges in such a system is the accuracy of level measurement, as ultrasonic sensors can be affected by surface ripples, foam, or inconsistent reflections. To address this, signal processing techniques like averaging multiple readings and applying digital filters are employed to smoothen the data.For future upgrades, the system could incorporate alternative sensors like capacitive or float sensors for more reliable detection in foamy or turbulent conditions. Adding an IoT module (e.g., ESP8266) would enable remote monitoring and control, and implementing a PID control algorithm could improve the precision and stability of the fluid level regulation.By refining these areas, the system can evolve into a more adaptable and intelligent solution for both industrial automation and smart home applications.

5. CONCLUSIONS

This project successfully demonstrates an ARM-based liquid level detection and fluid control system using an STM32F103C8T6 microcontroller. The system effectively monitors liquid levels and regulates fluid flow, ensuring automation and accuracy. By integrating ultrasonic sensors, a DC water pump, relay, and an LCD display, the design achieves real-time monitoring and efficient operation. The project highlights the importance of embedded systems in industries such as agriculture, water management, and healthcare, where precise fluid control is essential. With future enhancements like IoT connectivity, AI-based optimization, and improved sensor accuracy, this system can be further developed into a smart, scalable, and energy-efficient solution for various real-world applications.

REFERENCES

1. Icha, A. (2012). Book Review: Fluid Mechanics, by Frank M. White, McGraw-Hill Companies, Inc. 2011; ISBN-13 9780073529349. *Pure and applied geophysics*, *169*, 1325-1327.

2. Denn, M. M. (1980). Process fluid mechanics.

3. Cundiff, J. S. (2001). *Fluid power circuits and controls: fundamentals and applications*. CRC Press.

4. . De Silva, C. W. (2015). *Sensors and actuators: Engineering system instrumentation*.

5. Mehta, B. R., & Reddy, Y. J. (2014). *Industrial process automation systems: design and implementation*. Butterworth-Heinemann.

6. David, G. A. (2018). *Introduction to mechatronics and measurement systems*. MCGRAW-HILL EDUCATION.

7. Cundiff, J. S. (2001). *Fluid power circuits and controls: fundamentals and applications*. CRC Press.

8. Onwubolu, G. (2005). *Mechatronics: principles and applications*. Elsevier.

9. Gillum, D. R. (2009). *Industrial pressure, level, and density measurement*. Isa.

10. Zhu, Y. (2023). *Embedded Systems with ARM Cortex-M Microcontrollers in Assembly*. E-Man Press Llc.

11. Leier, M. DEVELOPMENT OF HANDS-ON EXERCISES FOR EMBEDDED SYSTEMS.

12. Mohan, N., Undeland, T. M., & Robbins, W. P. (2003). *Power electronics: converters, applications, and design*. John wiley & sons.

13. Bansal, R. K. (2004). *A textbook of fluid mechanics and hydraulic machines*. Laxmi publications.

14. Volk, M. (2013). *Pump characteristics and applications*. CRC Press.

15. Artan, M., Soydemir, M. U., & Şahin, S. (2020). ARM Based Hybrid Measurement System Design for Liquid Level Measurement with High Accuracy Under Vibrating Case. *Avrupa Bilim ve Teknoloji Dergisi*, 381-388.